SIMULATION/OPTIMIZATION TOOLS FOR ROBUST PUMPING STRATEGY DESIGN

Richard C. Peralta
SAF/IEI, AFRPA/EV, Utah State University (USU)
USU, Logan, UT 84322-4105
435-797-2786
peralta@cc.usu.edu

Co-author:
Ineke Kalwij, USU

Introduction

Simulation/Optimization MOdeling System (SOMOS) is used to compute mathematically optimal water management strategies for user-specified management problems (SS/OL, 2002b). A pumping strategy is a spatially and perhaps temporally distributed set of pumping rates. SOMOS, like other simulation/optimization (S/O) models, compute optimal strategies by coupling simulation (S) models with optimization algorithms. Common S models are MODFLOW and MT3DMS. Users of S models must input pumping strategies. Users of S/O models must input descriptors of the optimization problem to be solved.

SOMOS is extremely powerful. It has many features to speed and enhance pumping strategy design. For example, it includes many procedures for reducing the number of simulations needed to develop optimal strategies. SOMOS also has operations that increase the robustness or reliability of strategies it develops. These characteristics are important for the following reasons.

S/O models require numerous simulations in the process of computing optimal pumping strategies. In general, the more nonlinear the physical system and the optimization problem being addressed, the more simulations are required. If individual simulations require much time, optimization can be time-intensive.

Strategies designed using models of any type might not satisfy management goals in the field. This occurs because S models are merely approximations of physical systems. S/O model accuracy is only as good as that of the employed S models.

A robust strategy will achieve management goals even if the physical system differs from the model. Robustness is determined by systematically changing model assumptions and running simulations for each set of assumptions. A strategy's hydraulic conductivity (K) robustness range is the range of K multipliers for which the strategy will satisfy all constraints.

A reliable strategy has an estimable probability of achieving goals if the physical system differs from the simulation model in a statistically predictable manner. Reliability is determined by Monte Carlo analysis after a strategy is developed. Usually at least 100 realizations are developed from site statistical knowledge. Using the pumping strategy, one simulation is run per realization. The percentage of the simulations that satisfy all constraints is the strategy reliability.

This paper describes application of some SOMOS features for increasing pumping strategy robustness. These capabilities are easy to use.

Illustrative Example

At Umatilla Army Depot, Oregon, exist plumes of groundwater contaminated with Royal Demolition Explosive (RDX) and tri-nitro-toluene (TNT). Desired were pumping strategies to remediate these plumes. The management problem was to minimize cost of achieving cleanup to 2.1 and 2.8 ppb for RDX and TNT, respectively. Cost is a function of new installation, pumping and treatment rates, and fixed annual costs.

SOMOS was used to develop least cost strategies (SSOL, 2002a). The optimal pumping strategies will cost almost 60% less than the strategy of continuing current pumping. The optimal strategies require adding two extraction wells and changing pumping and recharge rates at existing wells and basins. These achieve cleanup within four years.

At this site, SOMOS identified hundreds of combinations of new well locations that will achieve cleanup in 4 years for about the same total flow rate, and hence cost about the same. Therefore it was appropriate to try to determine which of these hundreds of strategies is most appropriate. SOMOS operations that aid selecting the most desirable strategy include automated robustness analysis and stochastic (multiple realization) optimization. This allows well-siting based on robustness and ease of construction.

A California site illustrates stochastic optimization to determine desirable treatment facility size, or maximum total extraction flow rate (Aly and Peralta, 1999). Assuming a probability density function for hydraulic conductivity, optimization yields a trade-off curve between total flow rate and the reliability that optimal strategies for those rates will indeed remediate a plume within three years.

Closure

SOMOS has many features facilitating its use and the design of groundwater extraction and injection strategies. Included are deterministic and stochastic optimization, automated robustness evaluation, numerous constraints and objective functions, comprehensive optimization solver controls, and artificial intelligence. These help the designer incorporate his professional groundwater knowledge within the pumping system design. Depending on how much field data is available, they allow designing optimal strategies that are robust and /or reliable.

References

Aly, A.H. and R.C. Peralta. 1999. Optimal design of aquifer clean up systems under uncertainty using a neural network and a genetic algorithm. Water Resources Research, 35(8):2523-2532.

SS/OL. 2002a. Optimal pumping strategies for Umatilla Chemical Depot RDX and TNT plumes. Project completion report to U. S. Navy. 55 p.

Systems Simulation/Optimization Laboratory and HydroGeoSystems Group. 2002b. Simulation/Optimization MOdeling System (SOMOS)users manual. SS/OL, Dept. of Biological and Irrigation Engineering, Utah State University, Logan, Utah. 457 p.